Advanced Materials for Microturbines

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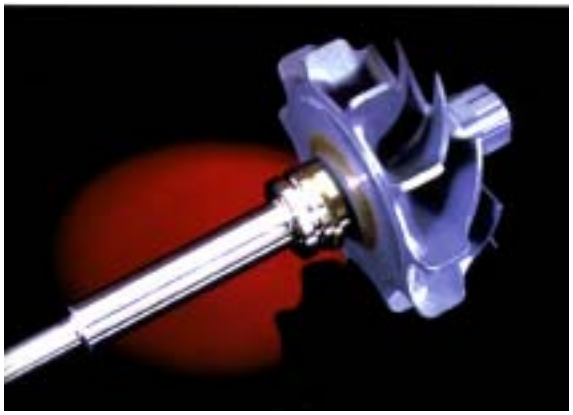
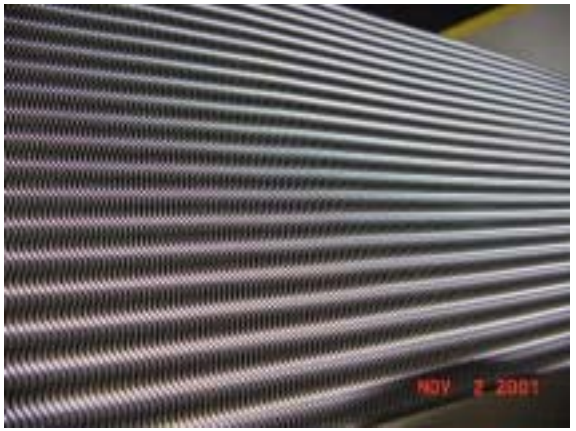
Materials Program Focuses on Needs Identified by Microturbine Contractors

- Si_3N_4 Ceramics
  - Environmental Stability (Honeywell, Kyocera, St. Gobain, ORNL)
  - Mechanical Properties (UDRI, ORNL)
  - Protective Coatings (ORNL)
  - Reliability and Life Prediction (NASA, ORNL)
  - NDE (ANL)
- Recuperator Materials
  - Creep-resistant Materials (600-750°C) (Materials Suppliers, ORNL)
  - Oxidation-resistant Materials (750-900°C) (Materials Suppliers, ORNL)
  - Microturbine Materials Test Facility (ORNL)
- Heat Sinks
  - High Conductivity Carbon Foam (ORNL)





Database of Materials Properties is being Developed for Designers, Materials Developers, and End Users

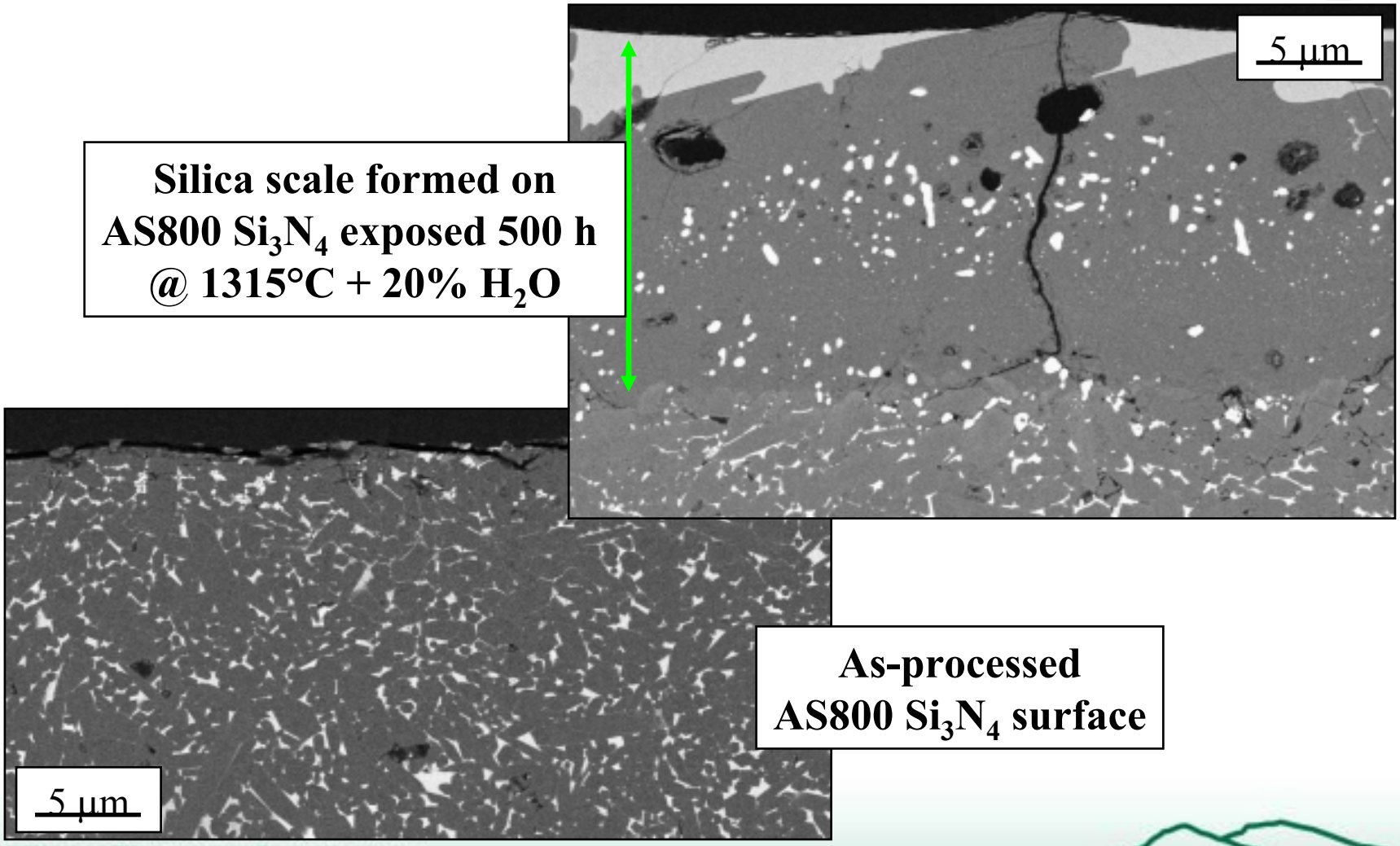
Methodology was Developed to Measure Properties of Complex-Shaped Ceramic Components

Evaluation of As-processed Surface Properties

Phase Identification
Residual Stress
NDE
Microstructure Characterization

Evaluation of Bulk Properties

Recent Engine Testing Indicates Si_3N_4 Reacts with Turbine Environments



OEMs were Polled to Determine Operating Conditions of Advanced Microturbines

Parameter	Strawman	Proposed
Temperature	1900 – 2300°F (1040 – 1260°C)	1800 – 2400°F
Total pressure	5 – 10 ATM	4 – 10 ATM
Water vapor	5 – 15%	3 – 20%
Gas velocity	0 – 250 fps	0 – Mach 1

United Technologies Research Center

Allison

Capstone

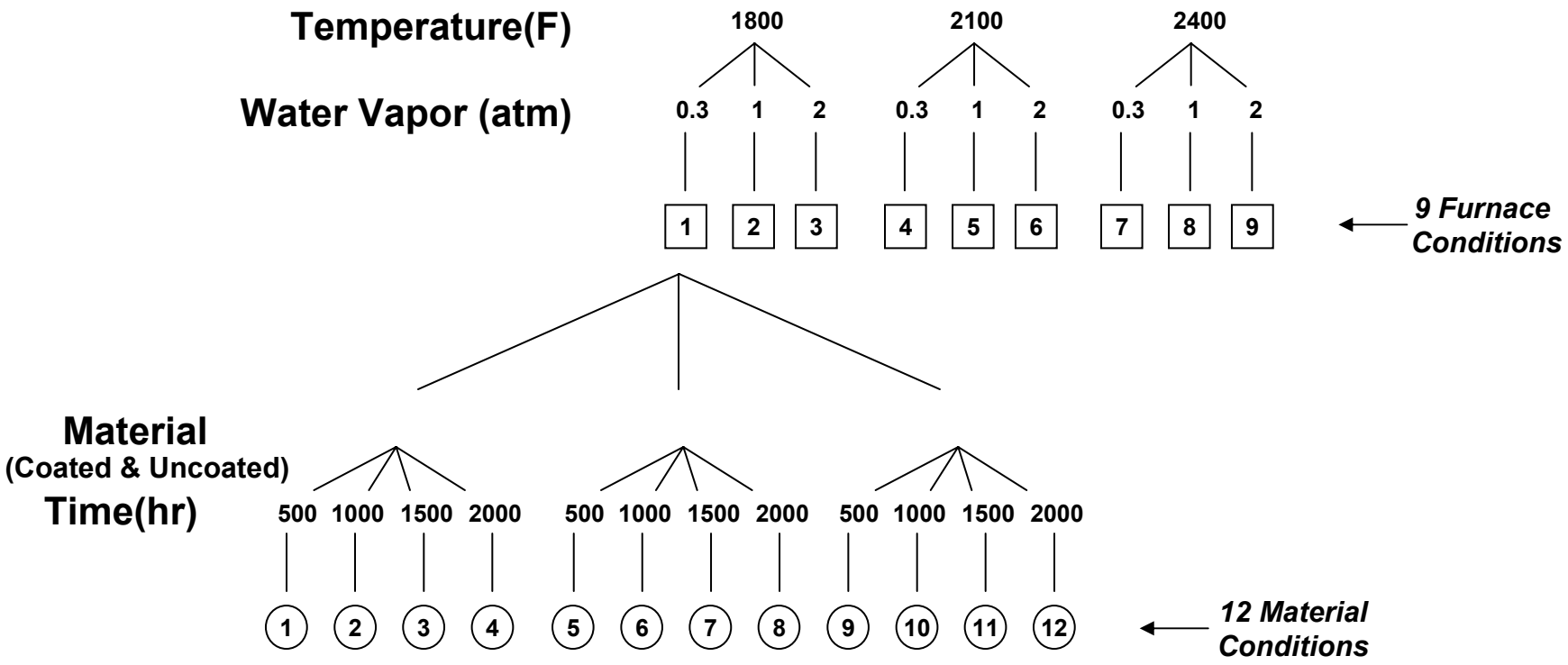
Williams

Teledyne

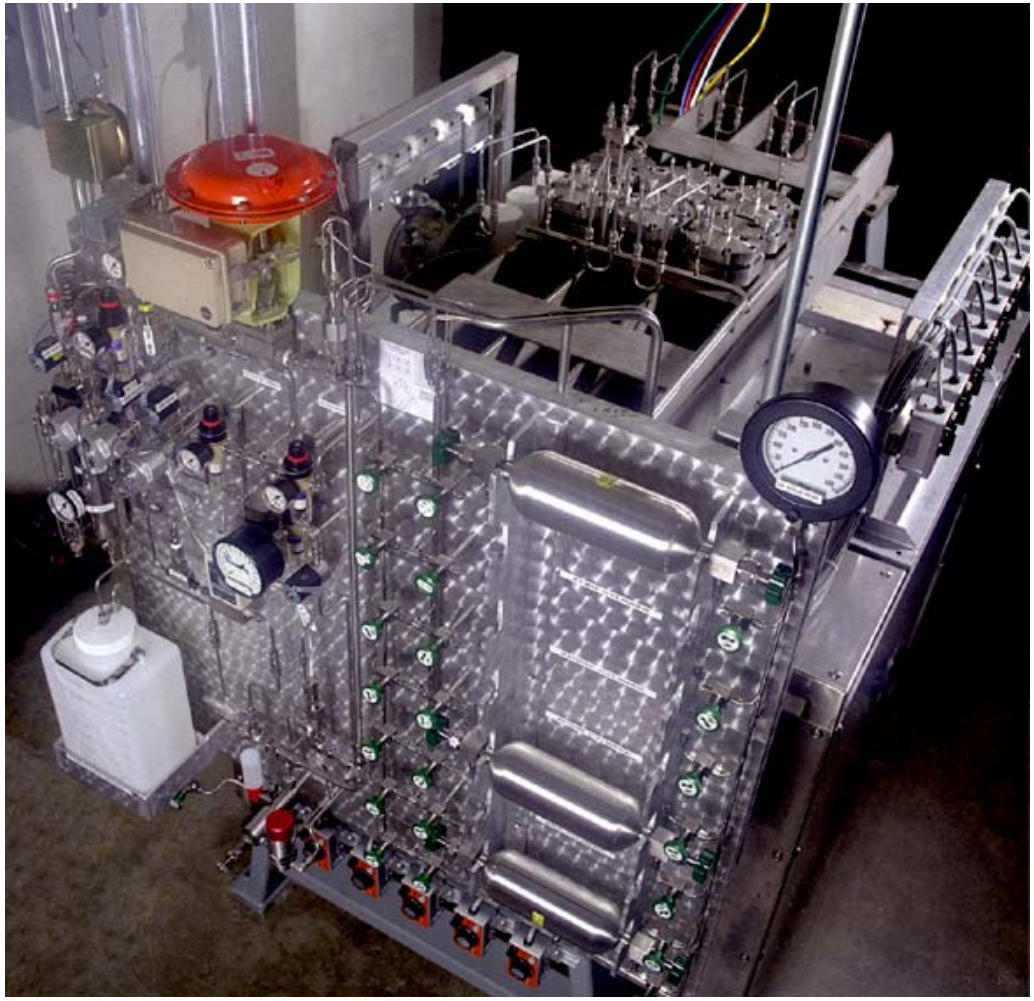
IR Energy Systems

Honeywell

Experimental Design was Developed from the Scoping Study



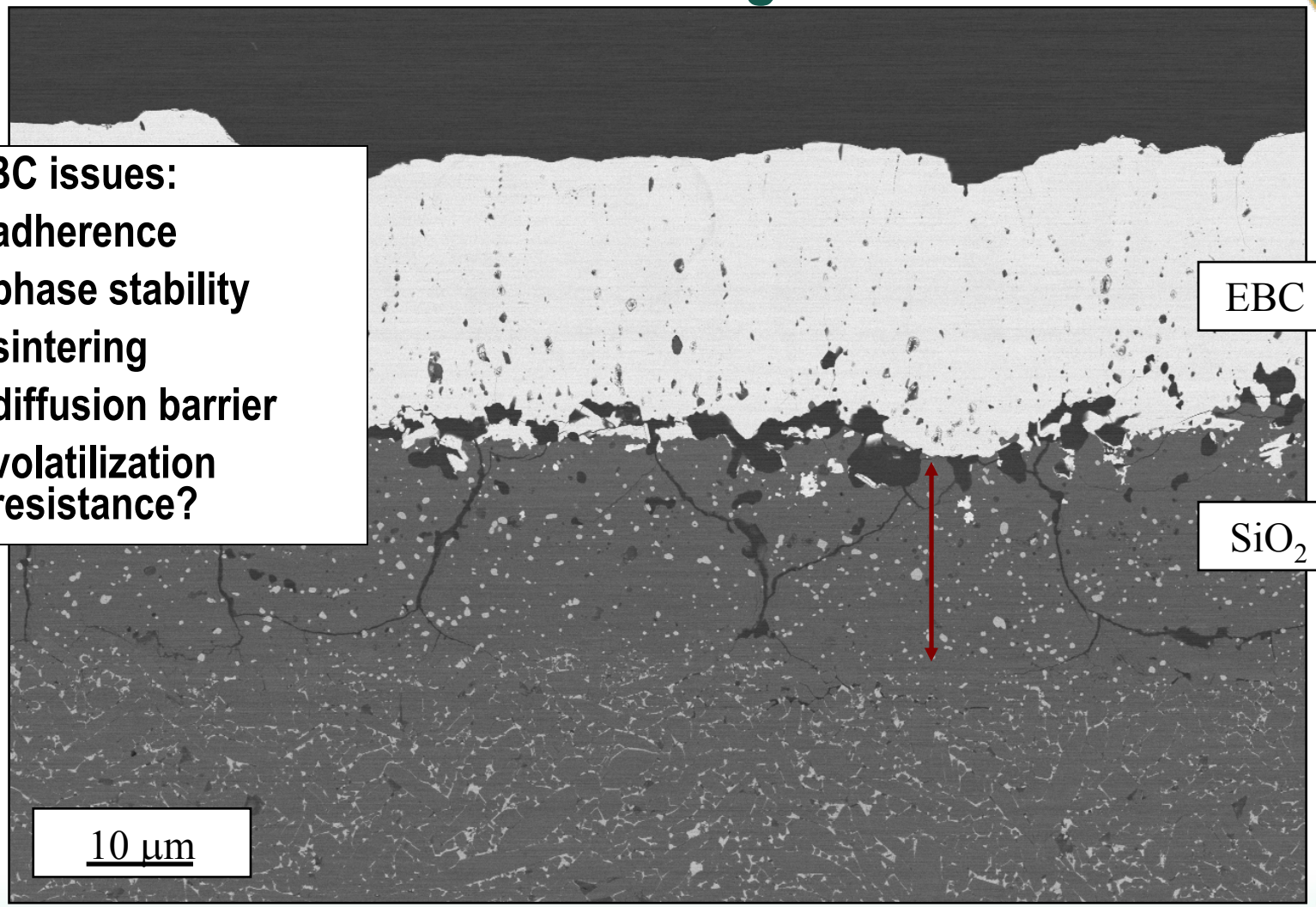
Hot-Section Materials are Evaluated in Simulated Microturbine Environments



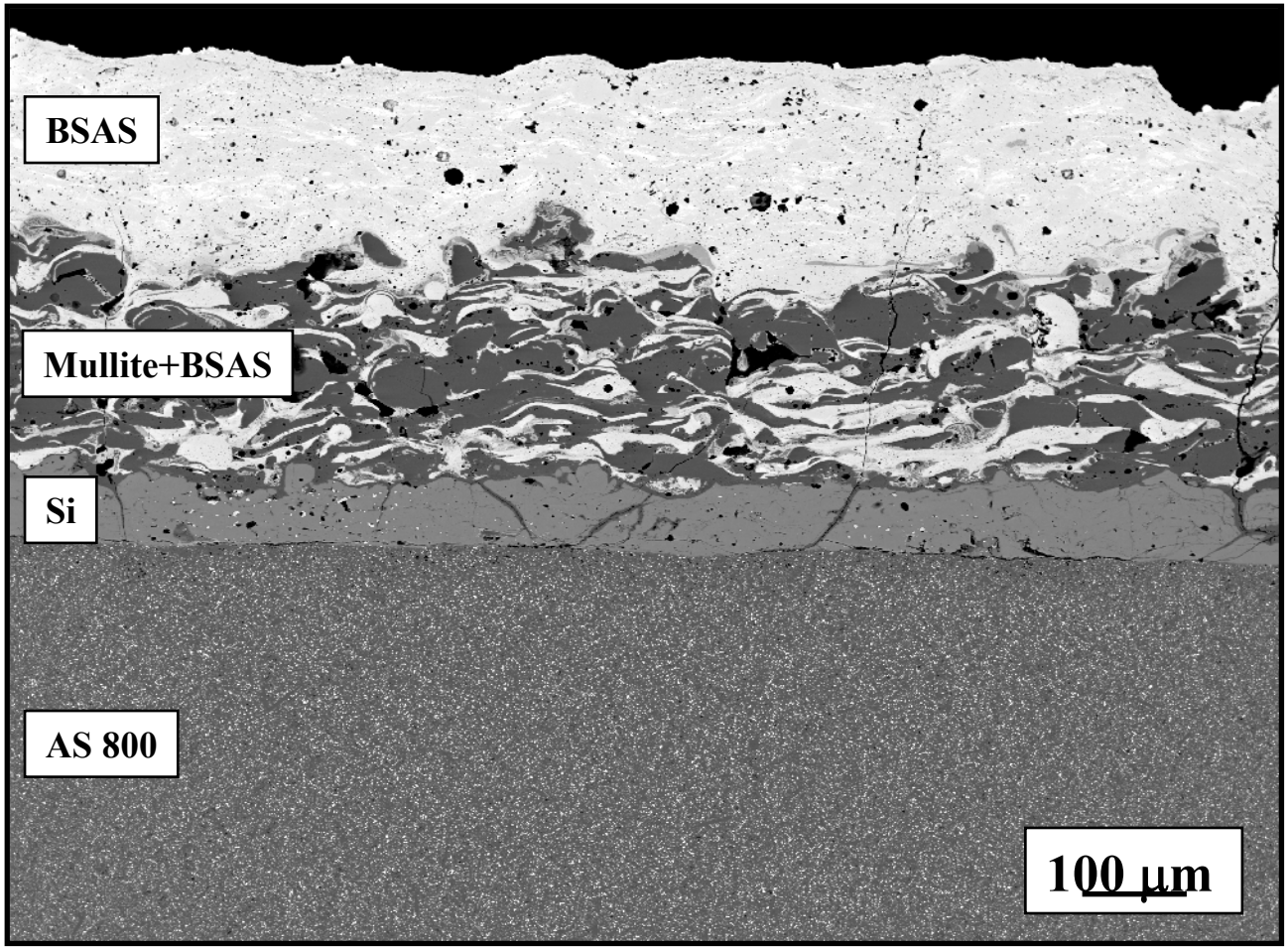
ORNL Keiser Rig

- Temperatures to 1500^{0}C
- Pressures to 20 atm
- Low Gas Velocity (0.1 m/s)
- Water Vapor Pressures to 4 atm
- Up to ~60 specimens/run
- 1000's of hours of exposure

EBCs Are Being Evaluated After Exposure in Keiser Rig

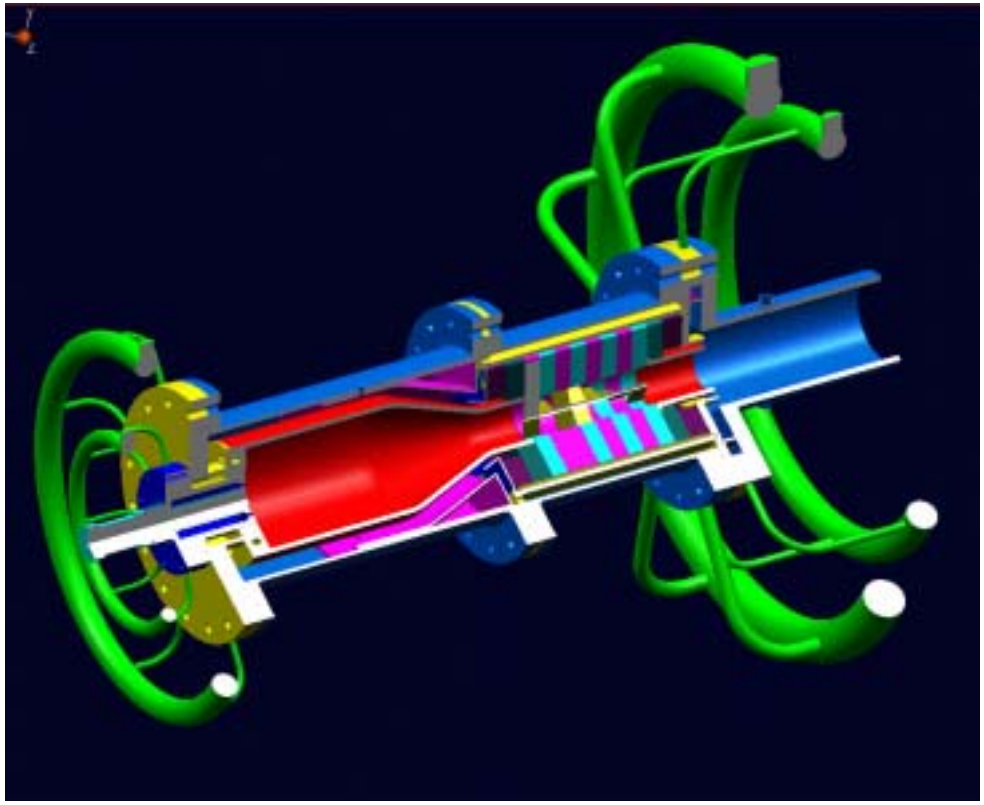


UTRC's Early Attempt To Put A "Mixed Layer" EBC On AS800 Silicon Nitride



Solar 150 thermally cycled (UTRC) then exposed for up to 2000 h in Keiser Rig @ 1200°C

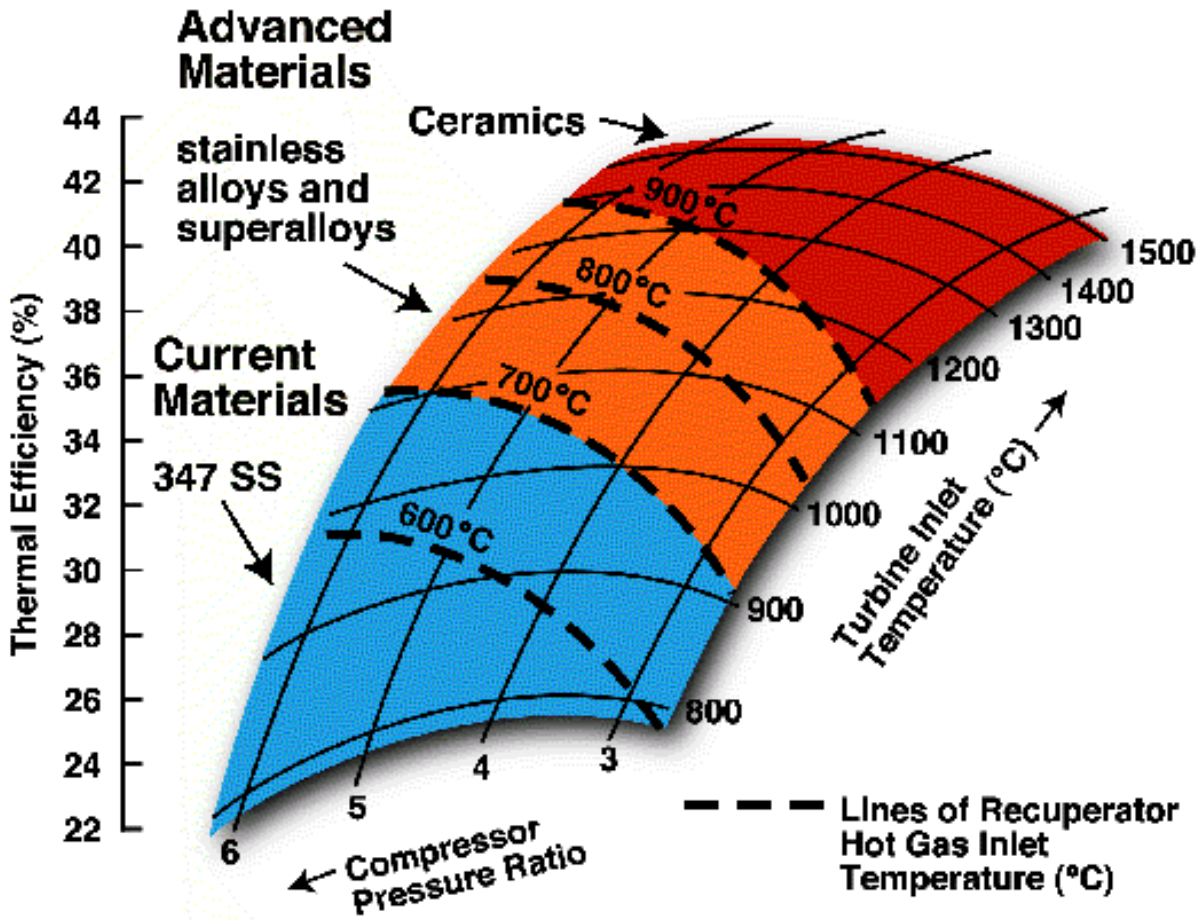
Environmental Test Center is Being Expanded to Include a High-Velocity Rig



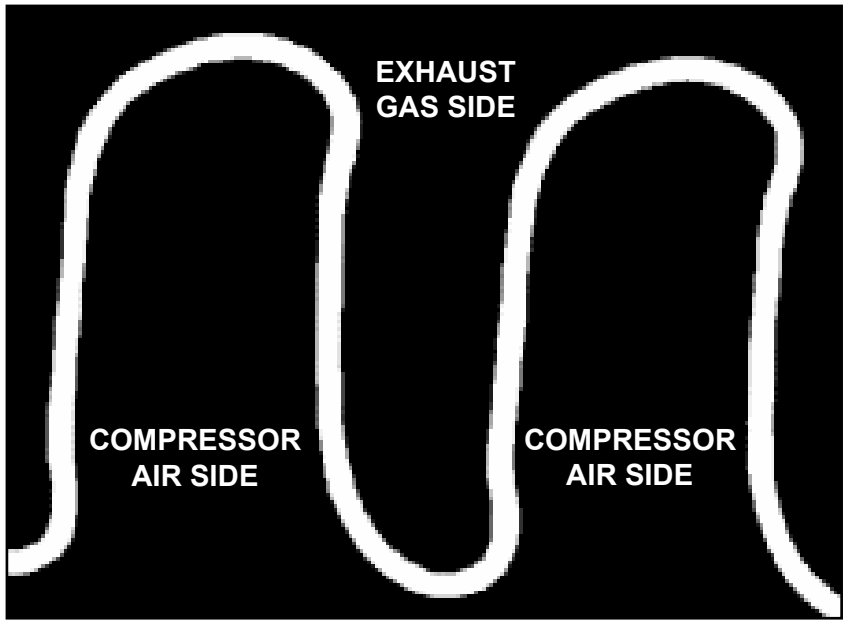
Honeywell Engines and Systems

- Temperatures to 1500^0C
- Pressures to 10 atm
- High Gas Velocity (900 m/s)
- Water Vapor Pressures to 4 atm
- 10-20 specimens/ run
- 100's of hours of exposure

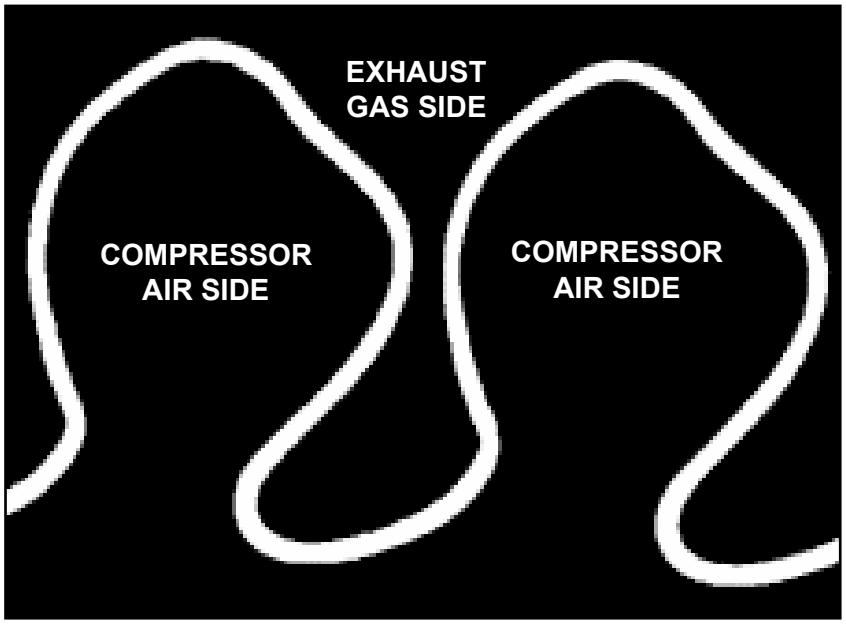
Materials Selection is Determined by the Recuperator Hot-Gas Inlet Temperature



Excessive Creep Can Close Up The Flow Channels In Recuperator Air-Cell



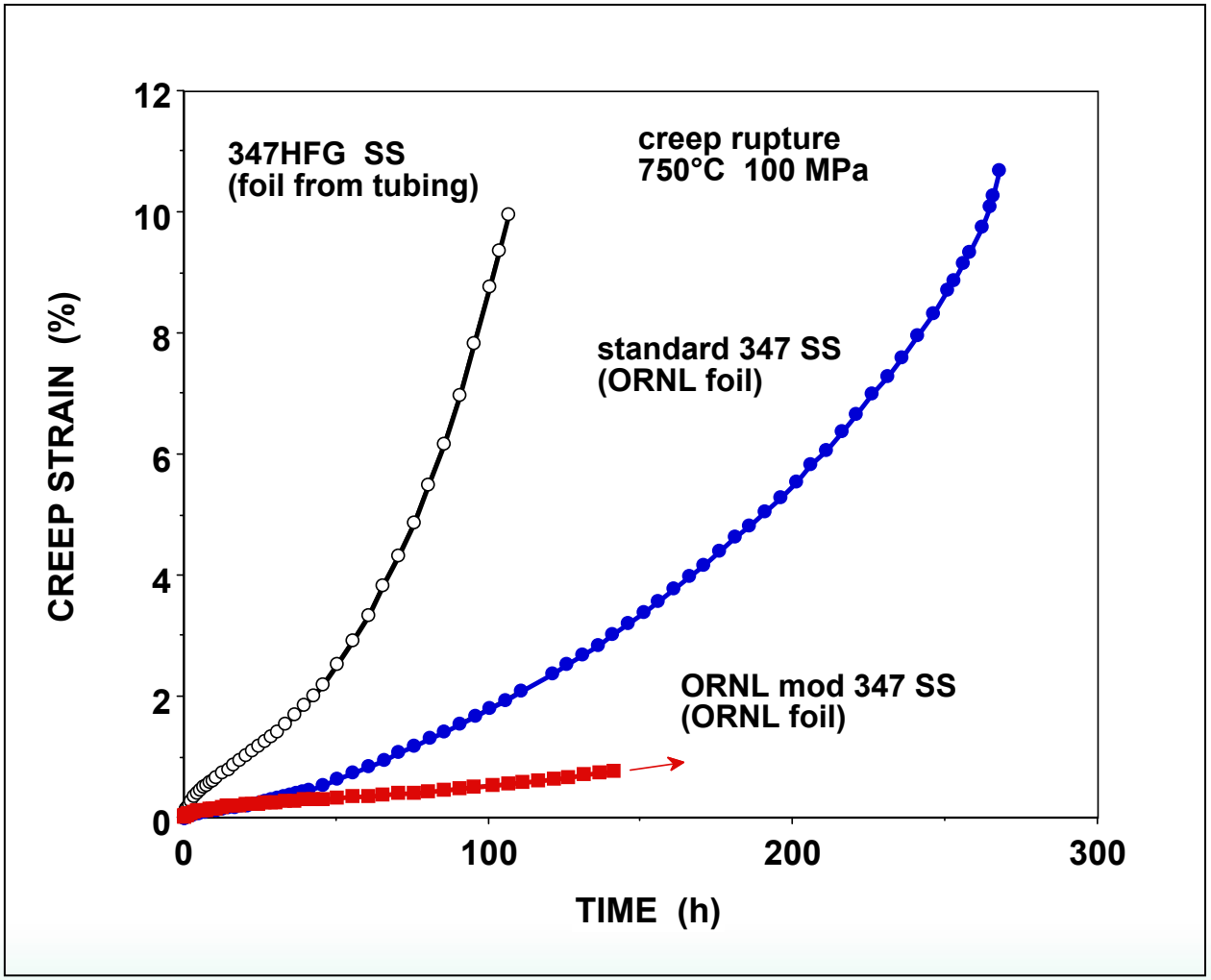
No Creep



Creep

- Oxidation becomes a problem at higher temperatures (water vapor)

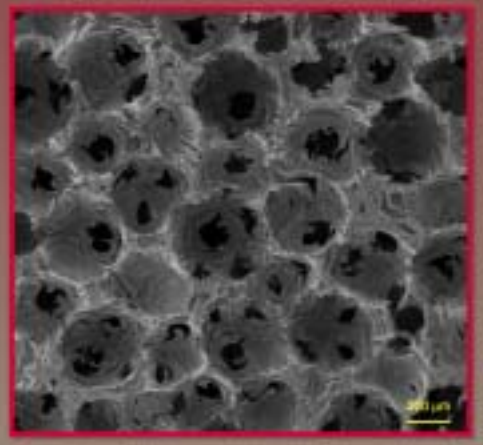
Alloy Development For Improved Foil Performance Must Be Targeted Directly At Creep Resistance

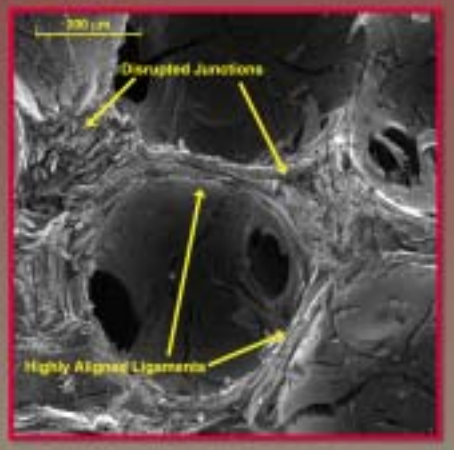


Recuperator Test Facility

High-Thermal Conductivity Carbon Foam

A unique carbon foam has been developed that exhibits high thermal conductivity and very high surface area, and is therefore ideal for heat transfer





Superior alignment along carbon foam ligament results in higher thermal conductivity

High-Conductivity Carbon Fiber

Carbon Foam Ligament

Material	Density [g/cm³]	Thermal Conductivity [W/m-K]
Aluminum 6061	2.7	180
Copper	8.9	400
High-Conductivity Carbon Fiber	2.2	1000
Synthetic Diamond	3.5	1900
Graphite Foam Ligament	*2.20*	*1700*
Perfect Diamond	3.5	2500

Ongoing Materials Projects Support the New Advanced Microturbine Contracts

- Collaborate with ceramic suppliers to evaluate the mechanical properties and environmental stability of silicon nitride
- Develop and evaluate corrosion-resistant coatings for silicon nitride
- Develop creep- and oxidation-resistant metals for higher temperature recuperators
- Develop a microturbine test facility to evaluate new recuperator materials

Good Communication Has Been Established With Program Participants

- Recuperator Workshop – May, 2000
- Distribution of Materials Quarterly Progress Reports
- Recuperator Materials Session at IGTI – June 2001
- Microturbine Materials Conference and Peer Review – June 2001
- Microturbine Applications Workshop – January 2002
- Advanced Recuperator Session at IGTI – June 2002